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Science Communication

Big Idea

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Let's Talk (and Read and Write) Science

In Science, teachers take pains to help students understand scientific concepts and principles. But for students to be considered truly scientifically literate, science communication should be a part of their education.

Much of our everyday life revolves around science. From the biggest issues of our time to the most trivial decisions that we make every day (what to eat for lunch?), we need our knowledge in science to guide us.

But how many of us are scientifically literate? Are we aware of how science is shaping our environment? Do we use scientific knowledge to identify questions and draw conclusions for decision making (Curriculum Planning & Development Division, 2013)? According to the Ministry of Education, our students should be capable of these and more to be considered literate in science.

"Scientific literacy is the goal of Science education, and it is to develop in every person an awareness of the role of science and of their role as citizens in a world driven by technology and science," says Dr Tang Kok Sing, an Assistant Professor at NIE.

But to achieve that goal, our students will need more than content knowledge. They will also need to know the language of science.

The Language of Science

Like every discipline, science has its own unique language. Scientific language is never just about words. Kok Sing explains that multimodal representations such as diagrams and graphs are part of it as well. In addition, scientific language

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- Tang Kok Sing,
Natural Sciences & Science Education Academic Group

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encompasses various text types, such as reports, arguments and explanations that are different from our everyday use of language.

"In order to learn science, one must have the ability to understand the language of science first," he says. While some seem to pick up the language naturally, there are many others who need a little more help.

It is not that teachers are not teaching the science language in class. "It's just that sometimes, it can be very implicit," observes Kok Sing, who is leading a research project on disciplinary literacy in Science classrooms.

For example, in a single lesson, teachers communicate with their students in myriad ways: They explain a scientific concept verbally, do a demonstration, and then draw a graph and write an equation with mathematical symbols. They also use language for different purposes, such as framing a question, describing an observation, explaining the reasoning, asserting a claim and providing evidence.

In order to learn science, one must have the ability to understand the language of science first.

- Kok Sing *on the importance of understanding the scientific language*

"It's quite common to assume that students can piece together all the different parts and understand the content and processes, but it's very hard, actually!" Kok Sing comments. "If we're going to teach students the language, it's got to be more explicit—it's got to link all these modes and purposes of communication together to form a coherent understanding."

Communicating in Science

Kok Sing and other NIE researchers have identified science communication as one of the key areas in Science education that they wish to explore (See box story online).

"Disciplinary literacy is looking at the science language in the teaching and learning context; it is something that needs to be taught to the students," says Kok Sing. Science communication is, however, more general. It is about how science is communicated between different parties.

"We should look at the different people involved. First, between scientists and scientists—how do they communicate?" asks Kok Sing. We can look at journals where they publish their findings, or conferences where they present and discuss experimental results.

Next, how is science communicated to the general public by the scientists so that it is easy to understand? Books on popular science, and even science centres and museums are good examples of that.

Third, and most importantly for Kok Sing and his colleagues, is the communication in classrooms—not just between teachers and students, but also among students themselves. In other words, they want to know how teachers and students are reading, writing and talking science in the classroom.

Tweaking the Communication Equation

What are the communication patterns like in our Science classrooms? For his project, Kok Sing and his team observed four teachers teaching upper secondary students. They found that writing took up about 10% of the time, but this was mostly limited to copying of text. Reading was almost zero. Talking happened a lot more, but usually, it was the teachers doing it. This situation prompted the researchers and teachers to do something about it for the next phase of the project.

For our students to become savvy science communicators, the equation needs to be tweaked. Reading is something that Kok Sing thinks the teachers can spend more time on.

Students often read the textbooks on their own for revision, but do they actually comprehend what they are reading? Teachers can try "scaffold reading" in class to make sure all students are reading with understanding.

"But don't just restrict it to the textbook. You can also read other sources; articles on popular science, for instance," advises Kok Sing, who was also involved in a project about harnessing popular culture in the teaching of the Sciences (See article in Issue 43: *Popular Media in the Physics Classroom*).

Tang Kok Sing is the Guest Editor of this issue. He is an Assistant Professor with the Natural Sciences & Science Education Academic Group at NIE. His research examines the disciplinary literacy of science, which comprises the specialized ways of talking, writing, representing and doing that are required in scientific knowledge construction. In particular, he examines how disciplinary literacy is a necessary process skill and designs scaffolding strategies to help students learn disciplinary literacy. Prior to joining NIE in 2011, he taught Physics and Project Work at Tampines Junior College and worked as an Educational Technology Officer at the Ministry of Education.

"There're a lot of such texts around. In this age of multimodalities, 'reading' also involves watching the news or science documentaries. Outside the classroom, there're also a lot of science."

Kok Sing and his team also worked with the teachers to plan for more student discussions and writing of different text types in science, such as explanation and argument. This is all part of educating students to write, talk, and even behave like scientists.

But it does not stop there. Students also need to know how science is being communicated to the public by scientists, especially for important issues concerning the environment, pollution or medical research.

"Science is so much a part of our everyday life! We read science everywhere, be it the TV or newspapers. We need to know how to read them in order to argue or to critique them," says Kok Sing.

Indeed, our students will need this ability in an increasingly complex world to be responsible citizens who make informed choices and decisions that not just affect themselves, but also the society and environment.

Useful Resource

Curriculum Planning & Development Division (2013). *Science Syllabus Primary 2014*. Retrieved from the Ministry of Education Singapore website: http://www.moe.gov.sg/education/syllabuses/sciences/files/science-primary-2014.pdf

Research

Arguing to Learn

Despite how it sounds, argumentation is not antagonistic! In fact, it drives both students and teachers alike to question and investigate claims they take for granted. This can lead to deeper learning.

To learn is to argue? NIE researchers Drs Tan Aik Ling and Peter Lee certainly think so!

"We're trying to emphasize that argumentation is not about victory, but about progress," says Aik Ling. "It is a process to move everybody's knowledge forward."

For their research, Aik Ling and Peter are using the pedagogical strategy of argumentation with NIE's student teachers. This is because they believe that teachers will not be able to implement the practice in their classrooms unless they have experienced it themselves.

Peter Lee (left) and Tan Aik Ling emphasize that argumentation is not about victory, but about progress

What Is Argumentation?

In science, it is vital to back up your claims and beliefs with evidence. Argumentation focuses on how students substantiate these claims to make sure they are valid.

"Argumentation is aligned with science communication and inquiry," Aik Ling explains. "Its structure is a means to help learners think in a logical manner, to be able to frame their answers and discussion in a more coherent, comprehensive and convincing manner."

To incorporate argumentation in the classroom, Peter and Aik Ling developed tasks that the pre-service teachers can engage in and argue about. To do this, they had to choose topics that were "arguable", which proved to be quite challenging.

Moreover, in order to argue convincingly, the student teachers need prior knowledge about the topic. Hence, Peter and Aik Ling provided them with resources in the form of an information package.

"The package gave their argumentation depth, even if they started out with low content mastery of the topic," Peter notes. "When we first started, we gave them access to the Internet, but that wasn't very helpful. A lot of time is spent searching, reading and making sense of it, which is something they can't afford to do in a classroom context with time limits."

Anatomy of an Argument

Another way of encouraging argumentation is to explicitly teach students the structure of an argument.

“Teaching the student the anatomy of an argument gives them a heightened awareness,” Aik Ling says. “So if you teach your teachers what argumentation looks like, when they are marking, they won’t just say ‘this is wrong’. They will tell the students why it is wrong; perhaps they don’t support their claim, or their evidence is inappropriate.”

It is especially interesting to analyse what people use as evidence. Aik Ling notes that other than traditional sources such as the textbook or Internet, younger children also think of everyday experiences as evidence.

She shares, “Using the same framework, a Primary 4 class was asked to make a shoe while they were studying the properties of materials. They realized then that shoes aren’t made of just one material. One student suggested that rubber can be a good material to make shoes, and when his classmates disputed it, the student countered, ‘How about *Crocs*!’ Nobody could argue with that! He didn’t talk about the scientific properties, and yet all his classmates were convinced because they all share the same everyday experiences.”

From there, Aik Ling facilitated their discussion so they could think more critically and support their argument with scientific explanation. Questions such as “What are the scientific properties of rubber which makes it a suitable material for shoes?” can be asked to guide them.

The Toulmin Model of Argumentation

Argumentation stems from a classical model: the Toulmin model. Dr Tan Aik Ling explains it thus:

“Argumentation is about a point and a counter-point. It is not about victory, but about progress—progress in knowledge, and progress in understanding how this knowledge comes about.

“There are six key components in the Toumin model: A claim, qualifier, rebuttal, warrant, backing and ground of evidence.

“The problem with this model is that there is little evidence that all six elements are being used in a natural, everyday setting. That is its limitation. However, it is relatively common to find at least the three components of claim, reasoning (warrant) and evidence (grounds) in everyday usage of argumentation.”

Emotions and Evidence

In many cases, argumentation is made complicated because of emotions. It is easier if it is purely an intellectual debate, but being humans, emotions are almost inevitable.

For example, when asked about the controversy about whether the MMR vaccine will lead to autism, the student teachers said, “I believe the scientific evidence that there is no link between the vaccination and autism, but as a parent, I’m still worried.” Or: “Even though my ‘science’ mind tells me this, I will still take the other stand.”

Outside of science, Aik Ling tells us to just take a look at social media. “People have different opinions, right? These opinions generally form part of the argumentation process,” she says.

However, on social media, much of the “evidence” stems from emotions and personal experiences, which can be inaccurate. While everyday experiences are important, Aik Ling stresses that solid and experimental evidence is needed in science to substantiate claims.

Deeper and Student-centric Learning

Argumentation gives more depth to the learning process, and raises questions that students and teachers alike had no reason to argue about previously. They may even realize that what they learn in the syllabus may not be the best model and there are alternatives out there.

On top of that, to engage in the approach of argumentation, students need good communication skills to explain their reasons for agreeing with or disputing a claim. They also need to be actively engaged in their learning and think critically, and have the ability to

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sieve out important and relevant information. They should also be willing to share. These are all characteristics of the 21st century competencies.

“The demands on the teachers are challenging, such as taking months to prepare a few good argumentation tasks,” Aik Ling notes.

But as Peter sums it up, “On the other hand, the pedagogy is very much student-focused. It allows students to think in a structured way and question more, which can be applied in many areas of their lives.”

Classroom

Explaining Science PRO-fessionally

Is there a mental structure that can help students answer science questions? Two teachers work hand in hand with NIE researchers to help their students articulate their explanations better.

Most students can make simple observations about a phenomenon, but it becomes a more challenging task when they have to use the right terms to explain their observations.

“One of the issues that I see with the girls here is their ability to use scientific terms,” shares Mrs Ken Oh Sihua, Acting Head of Department of Science at CHIJ Saint Joseph’s Convent (SJC). “They use words and descriptions of their own understanding, but it doesn’t translate to a scientific understanding.”

Ken Oh Sihua feels that while it is important to teach in her own style, it is also good to adopt new teaching approaches

The Subject Head of Physics at Northbrooks Secondary School, Mr Sim Yong Ming, shares the same sentiment. When it comes to open-ended questions, students may have the content knowledge but many struggle with the structure of an explanation.

They decided to work with NIE researchers by participating in an NIE research project to address this problem.

Working with Researchers

Led by Dr Tang Kok Sing, the project focuses on developing strategies for teaching the language of Science. Both researchers and teachers agree that the teachers’ current strategies should not be changed drastically.

“It was important to the researchers and us that we not change our teaching style, but explore how we could continue to teach in our own style while adopting the new approaches that were introduced,” Ken elaborates.

Sim Yong Ming wants to help his students explain scientific phenomena better

After 6 months of classroom observation, Kok Sing sat down with the teachers to ask how they were coping. They also discuss a few approaches that the teachers could try out.

“The NIE researchers and the teachers worked hand in hand to come up with some strategies,” Yong Ming says. “With their research point of view and our classroom experience, we made something workable and practical in the classroom.”

As Yong Ming was already using the Predict-Explain-Observe-Explain model in his Physics classroom, they implemented an approach to complement it and help with the *Explain* steps.

Principle, Reasoning, Outcome

They then implemented the Principle-Reasoning-Outcome (PRO) approach in explaining any phenomenon. Using this, students will indicate the principle or premise that the scientific theory is based on, provide a reasoning for why the phenomenon is happening based on the principle, and state its outcome.

"Many students do not know the structure of the explanation, or scientific logical reasoning," explains Yong Ming. "The PRO approach provides them with a guide to put what they know into words and sentences that are appropriate for the subject."

To help his students, he prepares worksheets for them, starting with a basic flowchart. This provides a mental structure that guides them in writing an explanation. First, are there scientific keywords that they need to use? Yong Ming begins by giving his students keywords first to help them identify and unpack their meaning.

Next, what are the connectors to use? He then provides them with language structure and connectors that can help in the building of the explanation.

Finally, does the answer address all parts of the questions? Ken explains that students are often not as meticulous in their reasoning as they should be.

Allowing for Mistakes

To teach students about chemical bonding, Ken Oh Sihua from CHIJ Saint Joseph's Convent uses the Principle-Reasoning-Outcome approach and complements it by letting them make mistakes and then realize it on their own.

She starts her lesson by showing a video about what happens when sodium chloride melts. Throughout the video, she would pause here and there to ask questions and get the class to fill up a customized worksheet, which requires the students to fill in the blanks and draw.

"As the teachers predicted, students just broke up the ionic compounds in their drawings," Ken notes. "We were able to pick out a couple of misconceptions there especially when we moved on to water. When ice melts into water, the molecules are still intact, it's still H2O. But the girls actually drew it as H on its own, and O on its own, so they actually broke down the entire molecule."

This is when Ken prompts them with simple questions to make them realize their mistake. "I asked them very simple questions like 'What is the chemical formula for ice?' and the students will tell us it's H2O," she says. "And by the time I ask them again, 'What about water? And gas?' It'll hit them and they'll understand what I'm trying to tell them."

Encouraging Students to Explore

The PRO model can be incorporated easily into the Science classroom to accompany demonstrations, hands-on activities or videos.

Students are encouraged to write down their first thoughts about a phenomenon or an idea, and then discuss why they think that way. "We don't put them down immediately if they are wrong," Ken says. "In terms of correcting them, we question them, and they actually get to realize by themselves that they are on the wrong path."

It is vital to allow students to make mistakes so they can remember and learn from it. Through such exploring, they can become more vocal and willing to experiment. Ken adds, smiling, "It's a bit of endurance training for me, and it tests my patience as well!"

Teachers Make a Difference

It is understandably not easy for teachers to tackle both the syllabus content and disciplinary literacy in depth, especially with time constraints.

However, Yong Ming points out that ultimately it is really about being aware of his actions and improving his existing teaching style. "Even before the project, I was already trying to excite my students," he says. "But the project made me think of more meaningful ways to help them."

Indeed, students became more enthusiastic about the subject after the implementation of the PRO approach. Ken shares that her students even asked if PRO can be introduced in lower secondary classes because they had such a lot of fun.

Yong Ming notes that according to research, students around the world are struggling with explanations. "But being part of this project brought about awareness that hey, we can do something about this problem."

Ken echoes his sentiment. "In the past, I would think that certain things cannot be done," she admits. "But now I know it's important for teachers to try something new that might be good for the students. As Thomas Edison observed, even if things go wrong, at least you would've found one way that doesn't work!"

Ken Oh Sihua is the Acting Head of Department of Science at CHIJ Saint Joseph's Convent. She has been teaching for 9 years. **Sim Yong Ming** is the Subject Head of Physics in Northbrooks Secondary School. He has been teaching for 4 years.

The Importance of Effective Communication

We communicate with others all the time. But how good are we at it? The English Language Institute of Singapore is helping teachers, and ultimately students, become effective communicators.

As an English Language Specialist at the English Language Institute of Singapore (ELIS) since 2011, Dr Caroline Ho has been conducting various workshops to help teachers become more effective communicators in subjects such as Science and Math. She gives her take on why teachers should and how they can communicate more effectively with their students, and how students can be encouraged to do the same.

Q: What is effective communication in the classroom?

Central to all that we do, it has to be the students who will benefit. We view effective communication as supporting students' learning, so it applies to all subject areas. We try to make it clear to schools that effective communication is more than just pronunciation, intonation or articulation. Communication also involves the teachers' classroom discourse and interaction that deepen thinking to help students internalize and process subject content.

We believe in teachers and students co-constructing knowledge together, particularly in the subjects that involve multimodal aspects of communication, for example, visual data such as graphs, charts, statistics.

Effective communication must take into account the context and purpose for which teachers and students are communicating. Given the emphasis on 21st century competencies, more demands are being made on the students to explain, justify and reason through problem-solving strategies. The interaction among students as they co-construct knowledge becomes important too. We want them to recognize the role of language in meaning making, and see communication as a collaborative activity. It shouldn't be just one-sided, as in teacher disseminating information, but two-way with teacher and/or students responding to each other to deepen content learning. Effective communication means that the receiver fully understands, comprehends and interprets what the speaker and/or writer has conveyed.

> By modelling effective communication as a Science teacher, your students will become aware of the norms and conventions of reading, writing, talking and thinking like a scientist.
>
> \- Caroline Ho,
> *English Language Specialist, English Language Institute of Singapore (ELIS)*

Q: Why is effective communication in subject learning important?

Teachers can model what effective communication looks like to students. We believe that modelling, thinking aloud and unpacking the thinking processes that are required to convey the content effectively will enable students to process and internalize the targeted subject matter.

If students can replicate this, they can then clearly articulate their own perspectives of what they are learning, their own logical reasoning and thinking processes. This makes thinking visible. It's even more important now with the emphasis on more knowledge-building, inquiry-based and problem-solving approaches—so rote learning will not do. Students need to learn how to work through their problems and articulate their reasons for why they have adopted a certain approach, and justify arguments put forth.

When we talk about literacy in the subjects, it is the ability to use language appropriately, meaningfully and precisely in a given subject area. It requires the teacher to be proficient in the language and subject knowledge. Subject teachers have to be conscious of how they construct meaningful dialogue with their students, how they can facilitate thinking and understanding of content through interactional modes of language use in the classroom. We are helping teachers with their classroom talk, interaction with students and questioning strategies.

We want to help teachers communicate their subject knowledge more clearly and effectively so that it is the students who will benefit.

- Caroline *on the importance of helping teachers communicate with their students better*

Caroline Ho has been an English Language Specialist at ELIS since 2011. She was formerly a language teacher educator and researcher at NIE. Prior to that, she served as a Specialist Inspector for English Language at the Ministry of Education. Caroline had also taught General Paper at a junior college.

Q: How is effective communication done in a subject like Science?

I've been working with Science teachers and that's where the collaboration with NIE comes in with one study. Science as a discipline demands that we look at evidence. You need to learn how to observe a phenomenon, create hypothesis to test what you see based on the evidence, and adapt your hypothesis or modify your assumptions.

When teaching, you have to help the students formulate very clear and precise explanations that address the specific demands of the questions. And what is tough is where students have to present scientific and logical reasoning, argument and justification to show the logical connection of the evidence and claims. All these skills become very critical: How you formulate your explanations, how you evaluate your explanations as new data/evidence comes in as part of the process of scientific inquiry.

So you can't talk about effective communication in a vacuum. It has to be in a specific context with a clear outcome. By modelling effective communication as a Science teacher, your students will become aware of the norms and conventions of reading, writing, talking and thinking like a scientist. There's now a greater awareness and attention on the part of the teachers as to what is involved because they want to help students, especially those who are weaker in English.

Q: If effective communication is not done well, what can go wrong?

We would be short-changing our students if we are not clear as to whether they have really understood what we have taught them despite getting good test or exam grades. The grades may show that they can clear whatever is required of them in assessments. But in my dialogue with teachers, I've learned that it may not always be clear to them as to whether students have really processed what they have learned and whether they can apply their learning despite doing well in Math and Science exams. In the long run, whether they are able to transfer those skills they have acquired even to other contexts and real-life situations, time will tell. In class, we wouldn't really know if you don't help them make their thinking visible, if it's not mediated through the communication in class. We may be fooling ourselves that students may be giving us the so-called "correct" answers, but they have actually not processed and mastered the content for themselves. This is what we need to continue to work on while they are with us in school.

Online Exclusives

Finding the Right Words

A Literature Review of Science Communication

Articulation and Writing in Science